Crosswell and Vertical Seismic Imaging at the Weyburn CO_2 Project

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RESEARCH OBJECTIVE

This work is part of a comprehensive time-lapse seismic monitoring program for monitoring a massive CO_2 flood in a thin fractured carbonate reservoir in EnCana's Weyburn field, located in the Williston Basin, southeast Saskatchewan, Canada. There are two goals to this project: (1) develop and deploy cost-effective technology that could track the detailed changes in CO_2 content as a function of time and (2) aid in the interpretation, validation, and integration of surface seismic data (from 3-C 3-D and 9-C 3-D surface and vertical seismic profiles [VSP]) to obtain an overall understanding of monitoring technologies for CO_2.

APPROACH

An extensive long-term CO_2 miscible injection is being operated by EnCana in its Weyburn field. The first phase of CO_2 injection started in September 2000. The flooding project is expected to expand over the Weyburn field area in the next several years. To determine applicability as well as refine the methods, a comprehensive plan for using geophysical methods for mapping fluid migration and dynamics is being carried out. In addition to the baseline and repeat 3-C 3-D and 9-C 3-D surface seismic and VSP surveys acquired by EnCana and the Colorado School of Mines (CSM) Reservoir Characterization Project, Berkeley Lab is carrying out high-resolution crosswell studies. The higher-resolution borehole data will be integrated with the surface seismic and reservoir engineering models to provide an overall understanding of reservoir definition and the dynamics of fluid migration. The crosswell seismic survey is intended to provide tomographic images of changes in reservoir properties at a meter scale or less. Integrated with the surface seismic survey and VSP, these data will provide proper scaling relationships for understanding overall flow behaviors of the CO_2 fluid at the reservoir dimensions. We will closely study the trade-off between the spatial resolution and spatial coverage of surface methods and borehole methods.

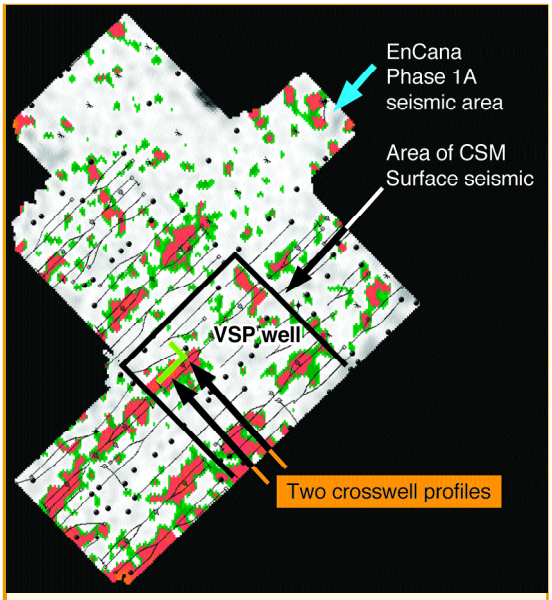

Figure 1. Location of the two vertical crosswell profiles and the VSP acquired in the fall of 2002, relative to the EnCana surface seismic and the CSM surface seismic

ACCOMPLISHMENTS

The main activities during the last year were a successful implementation of the vertical crosswell and VSP program. We planned and carried out two crosswell seismic profiles in three vertical wells surrounding one of the injection patterns (see Figure 1 for location relative to surface seismic and relative to the injection wells and producers). These profiles provided data parallel and perpendicular to the injector. The objective was to acquire high-resolution crosswell seismic images by using downhole seismic sources and receivers in separate vertical wells, as well as data with sufficient resolution (estimated at a scale of 1 to 2 m) to monitor CO_2 flood front movement and sequestration within the Midale reservoir zones and (most importantly) possible migration from the reservoir into other formations. After the completion of the crosswell, a VSP was run in the center well at the two offsets used for the crosswell. The source was an I/O multi-component vibrator used in the CSM surface seismic work.

SIGNIFICANCE

Both EnCana's and CSM's 4-D results have shown strong seismic anomalies that effectively correlate with the performance in the CO_2 flood front movements and conformance efficiency (supported largely by information such as production data and tracer study). However, EnCana's 4-D surface seismic has also produced some unexpected results. For example, the patterns of the subject VSP and crosswell have so far behaved quite abnormally. It has not yet generated any production response, even after it had received 3.4 billion ft^3 CO_2 (or equivalently 12.3% HCPV [hydrocarbon pore volume], an amount that would have made a normal pattern yield good production response). EnCana's 4-D data further show significant time delay at and below the reservoir layers and seismic energy attenuation, both indicating a significant amount of CO_2 gas accumulated near or above the reservoir. With all the information combined, we believe that a large portion (or even all) of the injected volume may have migrated into the overlying rocks and sequestered there. This likelihood indicates that monitoring this (and other) phenomena using high-resolution crosswell seismic technology may be required to detect zones of uncertainty in CO_2 floods.

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